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POINT-CONTACT SEMICONDUCTOR PHOTOCELL

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This present invention relates to photocells and more particularly to point-contact semiconductor photocells.

Photocells are usually divided into two distinct classes, one type being a photoelectric cell and the other a photoconductive cell. The device of the present invention may alternately be used as either a photoelectric or photoconductive cell, depending upon the external conditions established. A photoelectric cell will generate a current in a closed electrical circuit which is proportional to the intensity of the radiant energy received by the cell. On the other hand, a photoconductive photocell will change its electrical resistance with illumination and as it has nonlinear characteristics it will rectify an applied A.C. signal. The photoelectric or photoconductive phenomenon occurring in a semiconductor point-contact photocell may be explained in relatively simple terms, while a rigorous treatment of the subject requires quantum mechanics, calculations and equations. It might further be added that much is yet left to be discovered and explained in the field of semi-conductors in general and semiconductor photocells in particular. The simple explanation to follow requires a familiarity with the terms relating to semiconductors defined in the October, 1954 issue of "Proceedings of the IRE," pages 1506 through 1508.

Semiconductors, such as germanium, silicon, germanium-slicon alloy, indium-antimonite, aluminum-antimonite, gallium-antimonite, indium-arsenite, aluminum-arsenite, gallium-arsenite, lead-sulfide, lead-telluride, lead-selenide, cadmium-sulfide, cadmium-telluride, cadmium-selenide, or others hereinafter to be discussed, have been found to be extremely useful in electrical devices for translating electromagnetic energy, such as light or radiant energy for the generation or control of electric currents. In particular, these semiconductor devices have been utilized for sensing light and other forms of radiant energy and for amplifying or rectifying electrical input signals.

Basic to the theory of operation of semiconductor devices is the concept that current may be carried in two distinctly different manners; namely, "conduction by electrons" or "excess electron conduction," and "conduction by holes," or "deficit electron conduction." The fact that electrical conductivity by both of these processes may occur simultaneously and separably in a semiconductor specimen affords a basis for explaining the electrical behavior of semiconductor devices. One manner in which the conductivity of a semiconductor specimen may be established is by the addition of "active impurities" to the base semiconductor material.

In the semiconductor art, the term "active impurities" is used to denote those impurities which affect the electrical characteristics of a semiconductor material as distinguished from other impurities which have no appreciable effect upon these characteristics. Generally, active impurities are added intentionally to the semiconductor material for producing single crystals having predetermined electrical characteristics.

Active impurities are classified as either donors, such as antimony, arsenic, bismuth, and phosphorous, or acceptors, such as indium, gallium, thallium, boron, and aluminum. A region of semiconductor material containing an excess of donor impurities and yielding an excess of free electrons is considered to be an impurity-doped N-type region. An impurity-doped, P-type region is one containing an excess of acceptor impurities resulting in a deficit of electrons, or stated differently, an excess of holes. In other words, an N-type region is one characterized by electron conductivity, whereas a P-type region is one characterized by hole conductivity.

Presently it is thought that when a photon of radiant energy (either in the heat or infra-red, or in the light or visible portion of the electro-magnetic wave spectrum), strikes the surface of a semiconductor material, an electron and corresponding hole are produced as a pair. It is the flow of either these holes or electrons which produces conduction in the device which utilizes an N-type crystal as herein arbitrarily described. This conduction is mostly caused by holes which because of being surrounded by N-type impurity atoms are also called minority carriers. The generation rate, i.e., the time rate of creation of electron-hole pairs is a function of the number of photons which impinge upon the semiconductor crystal and which are not reflected at the surface of the crystal.

Unfortunately, after the electron-hole pairs are thus produced, there is a tendency for them to recombine. That is, the minority carrier has a tendency to recombine with an impurity atom to cause both the electron and hole to disappear. This recombination has been theorized to depend at least in part upon the following parameters: perfection of the semiconductor crystal, resistivity of the semiconductor crystal, surface condition of the semiconductor crystal, or surface-to-volume ratio of the semiconductor crystal.

In order to reduce the recombination rate it has been found desirable to place the collector junction, which is the point contact, close to that portion of the crystal at which the light or radiant energy impinges. When the point contact is too close to the location on the semiconductor crystal where the light impinges, both a production and a theoretical problem are encountered. If the crystal is made too small then in the manufacture of the photocell the pointed end of the whisker element may entirely miss striking the crystals so that there will in fact be no point contact made at all. Further, even though a small crystal permits a more efficient collection of carriers a larger crystal permits a more efficient collection of light. As an upper limit, the crystal cannot be made too large, else there will be too great a distance between the point contact position and the point or portion of the crystal wherein the photons impinge. Minority carriers will therefore have too great a distance to travel to the aforementioned collector point contact. As a result, since minority carriers tend to diffuse and recombine with impurity atoms in the crystal, very few will actually reach the point contact to produce any appreciable conduction. The presently accepted theory suggests that the greatest loss of minority carriers by recombination takes place at the surface of the crystal. Accordingly, the most advantageously designed crystal configuration, to reduce the degree of recombination, would call for the use of a spherically-shaped crystal. This is true because the ratio of surface-to-volume of a sphere is the smallest of any possible geometrical configuration.

It would thus appear that a photocell making use of a spherical semiconductor crystal with an associated point-contact would be the best solution to the aforementioned problem, namely, it would have the lowest possible re-